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Transfer of Science to industry in Wind Energy

Madsen, Peter Hauge

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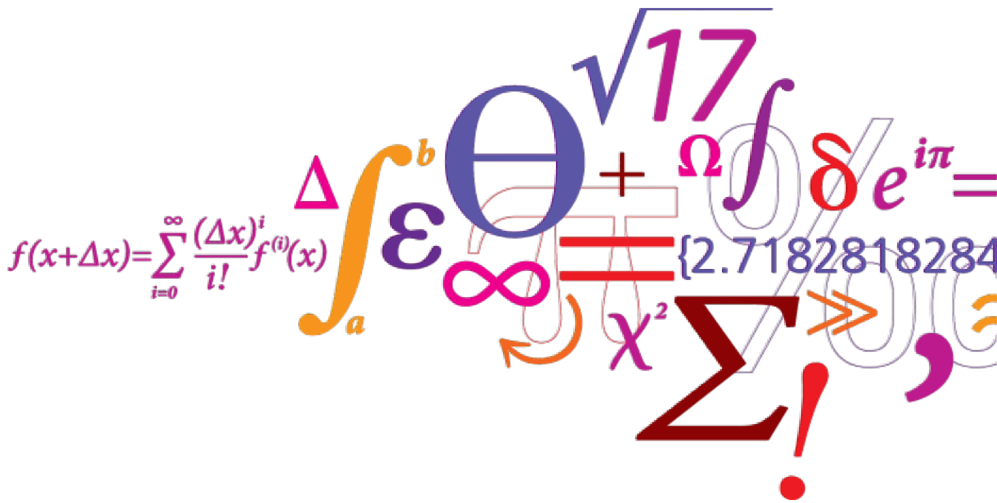
Transfer of Science to Industry in Wind Energy

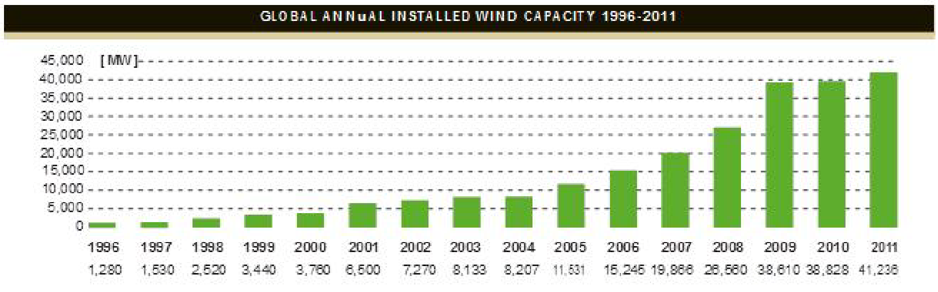
AAAS 2012 Scientific Breakthroughs: Renewable Energy

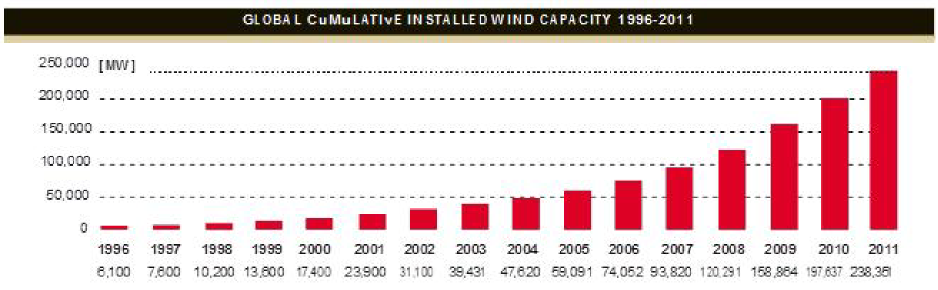
Peter Hauge Madsen
Head of Department
The Technical University of Denmark

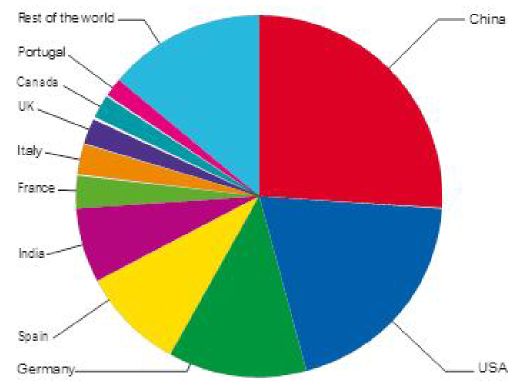
February 17, 2012



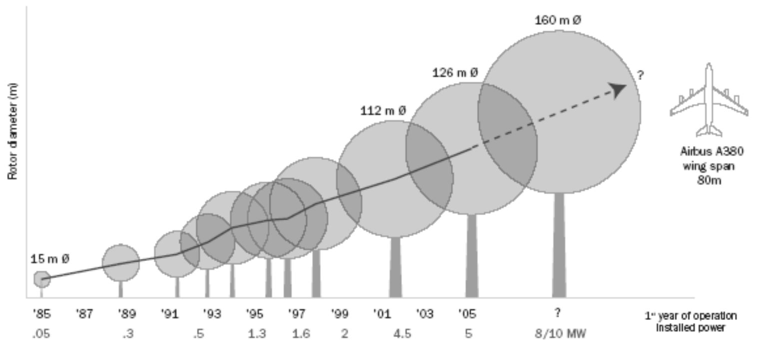
Wind energy – a recent example of science based technology development and dissemination





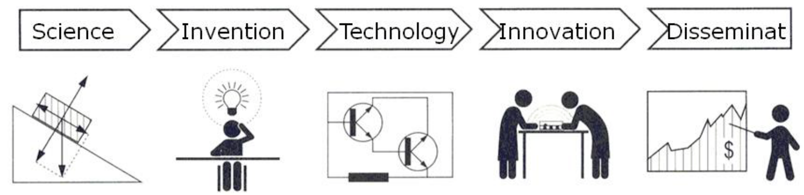


GWEC Global Wind Statistics 2011



Wind Energy - a science based technology

Poul la Cour at Askov 1891-1903



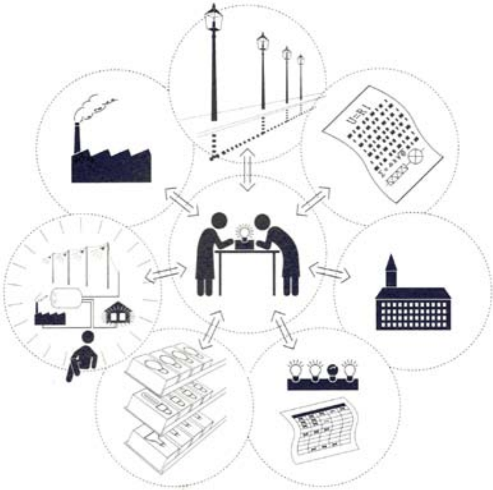
The new 6 MW offshore wind turbine by Siemens, from http://www.siemens.com/press/en/presspicture

Development of the electricity producing wind turbine in Denmark

Askov 1891-1903

Gedser 1957

Risø 1979



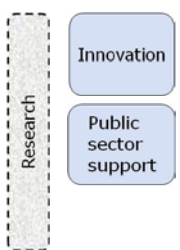
Interaction mechanisms: Science-industry

Concept development

- Demonstration
- Proof of concept

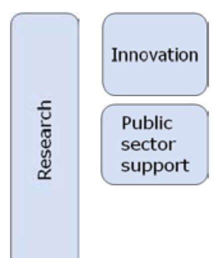
Documentation

- System test
- Design basis
- Basic design requirements
- System approval

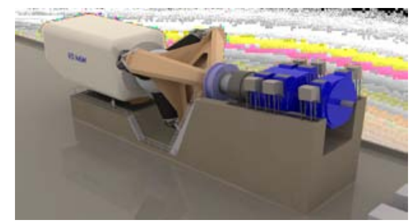


Development

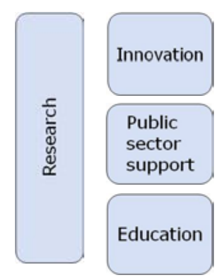
- Applied research, design tools, resource mapping
- Int. standardization



Industrialization



- Basic strategic research
- Integrated tools
- Validation



Patents and education

International wind turbine standards - IEC

a) Safety & functional requirements

↓

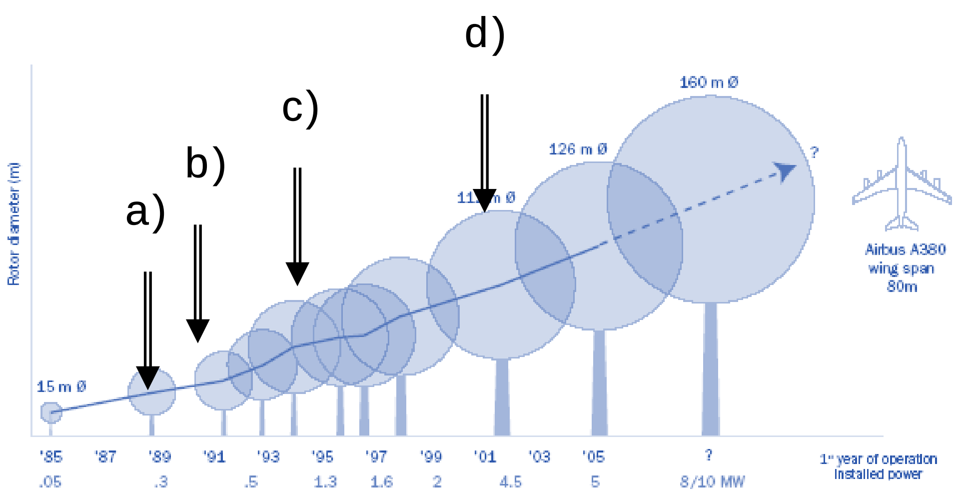
b) Test methods

↓

c) Certification procedures

↓

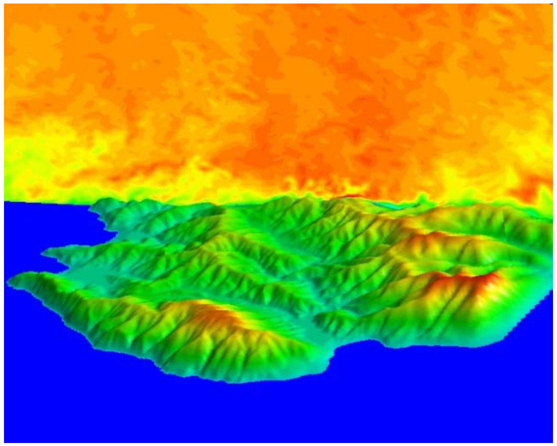
d) Interfaces & Component

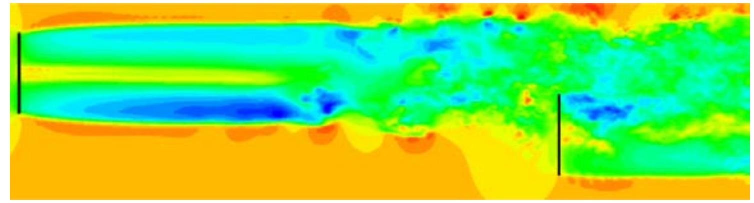


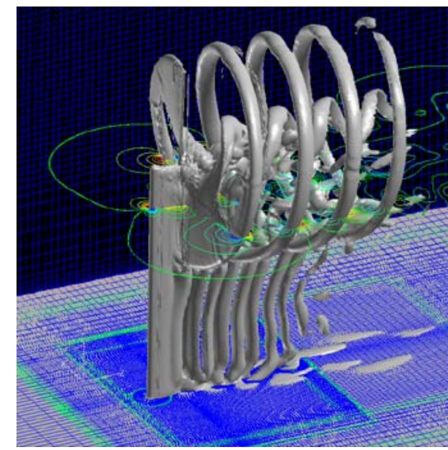
IEC TC88: IEC 61400 series:

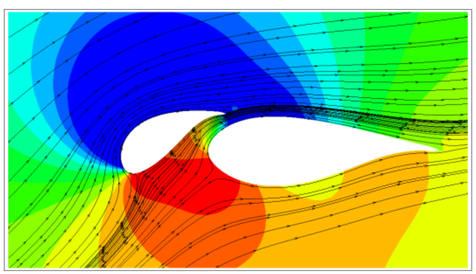
IEC 61400-1 Design requirements
IEC 61400-2 Small wind turbines
IEC 61400-3 Design requirements for offshore wind turbines
IEC 61400-4 Gears for wind turbines
IEC 61400-(5) Wind Turbine Rotor Blades
IEC 61400-11, Acoustic noise measurement techniques
IEC 61400-12-1 Power performance measurements
IEC 61400-13 Measurement of mechanical loads
IEC 61400-14 Declaration of sound power level and tonality
IEC 61400-21 Measurement of power quality characteristics
IEC 61400-22 Conformity Testing and Certification of wind turbines
IEC 61400-23 TR Full scale structural blade testing
IEC 61400-24 TR Lightning protection
IEC 61400-25-(1-6) Communication
IEC 61400-26 TS Availability
IEC 61400-27 Electrical simulation models for wind power generation

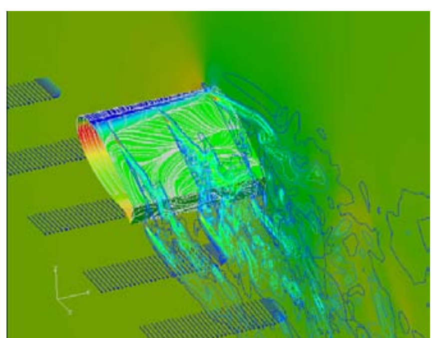
Advanced Design Tools for WT Aerodynamics -modeling and exp. validation

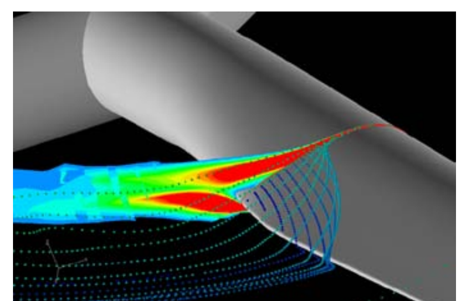








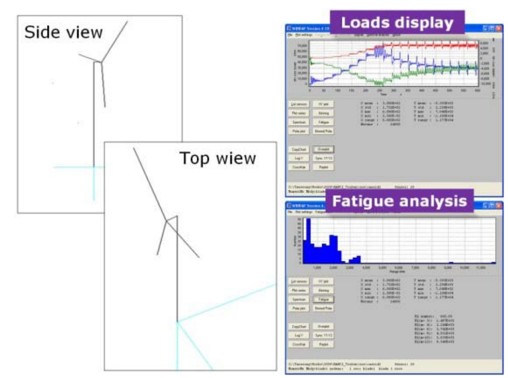




HAWC2 – Risø DTU's code for wind turbine load and response

- **A tool for simulation of wind turbine load & response in time domain.**
  - Normal onshore turbines; 3B, 2B, pitch control, (active) stall
  - Offshore turbines (monopiles, tripods, jackets)
  - Floating turbines (HYWIND concept for now, later... Sway, Poseidon).
- Based on a multibody formulation, which gives great flexibility

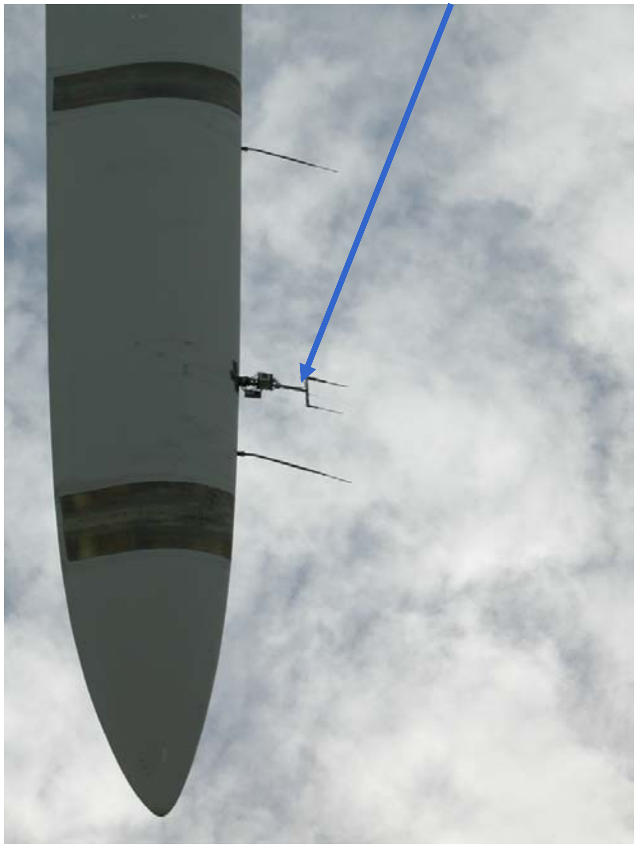
- **It is a knowledge platform!**
  - New research/models are continuously implemented and updated.
  - Core is closed source. E.g. Structure, aerodynamics, hydrodynamics, solver...
  - Submodels are open-source. E.g. water kinematics, standard controllers, generator models.



DAN-AERO MW-exp. (Risø, LM, Siemens, Vestas, DONG Energy)

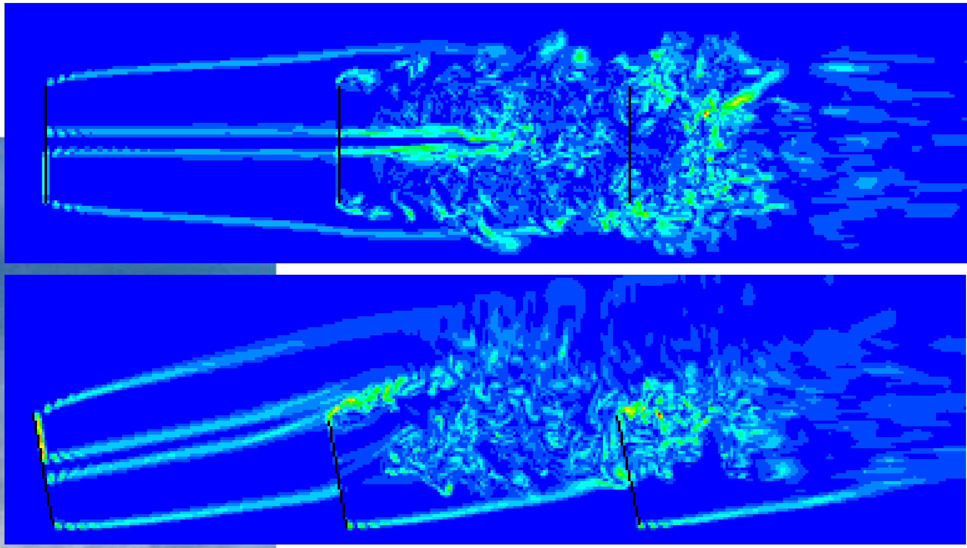
Pressure and inflow measurements on the NM80 turbine in the Tjaereborg wind farm

high frequency inflow sensors



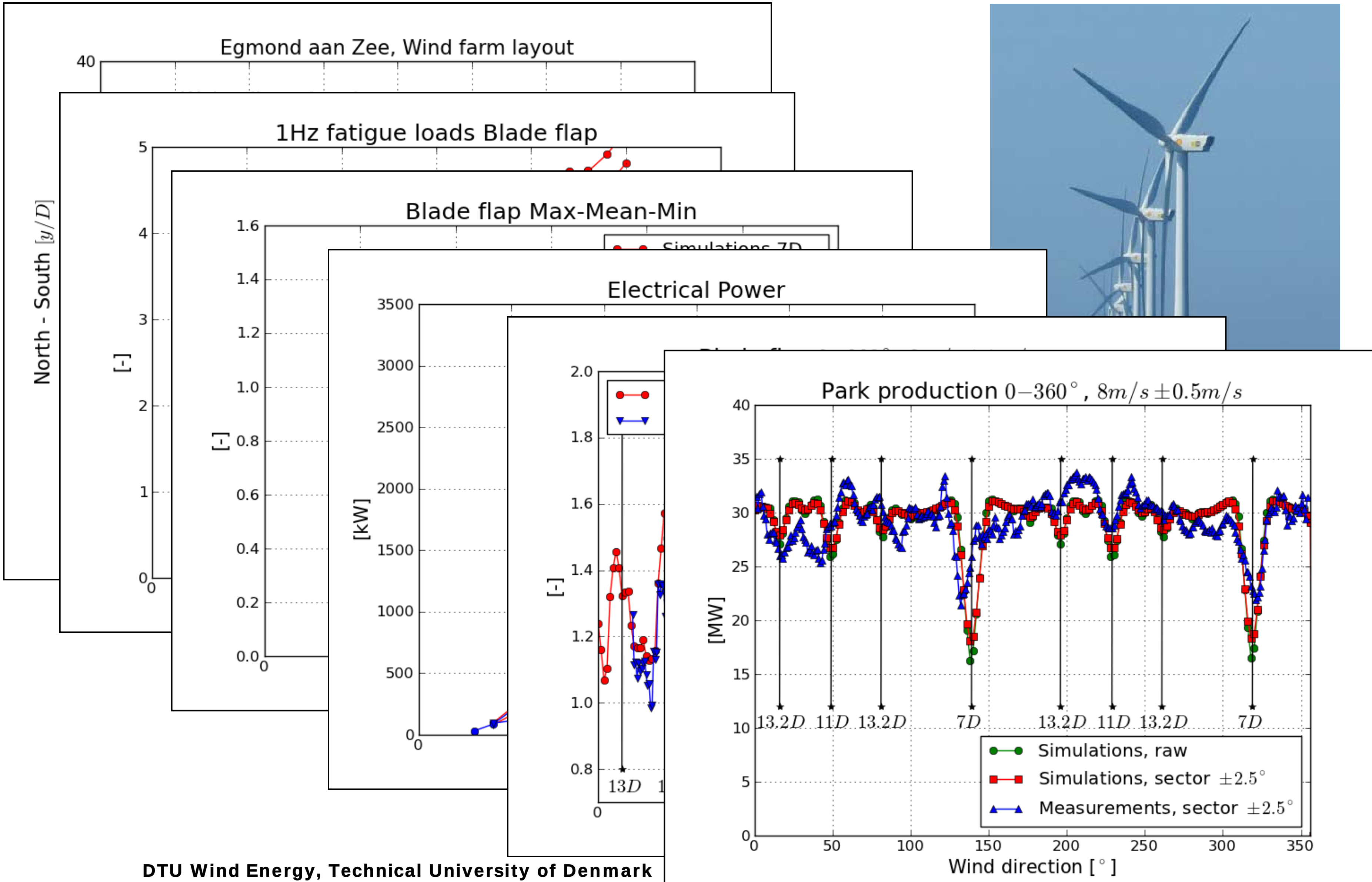
five hole pitot tubes

Wake effects – a complex flow essential for performance and loads



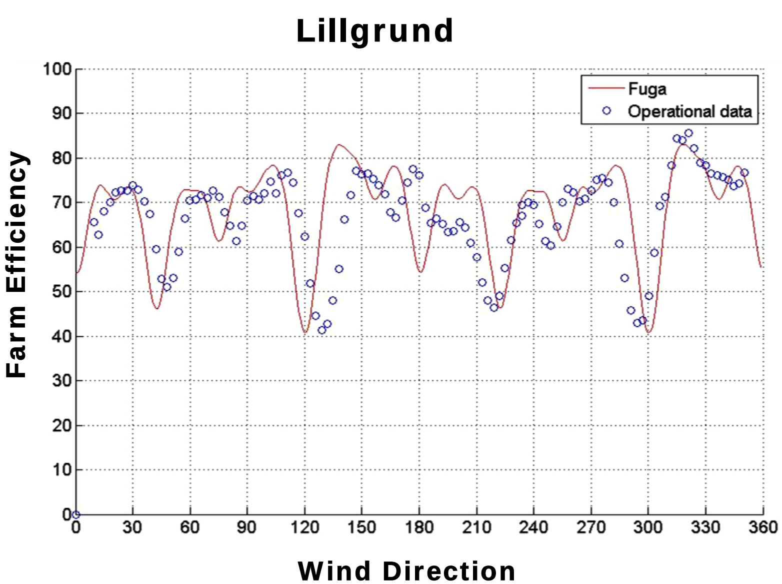
CFD – Large eddy simulation

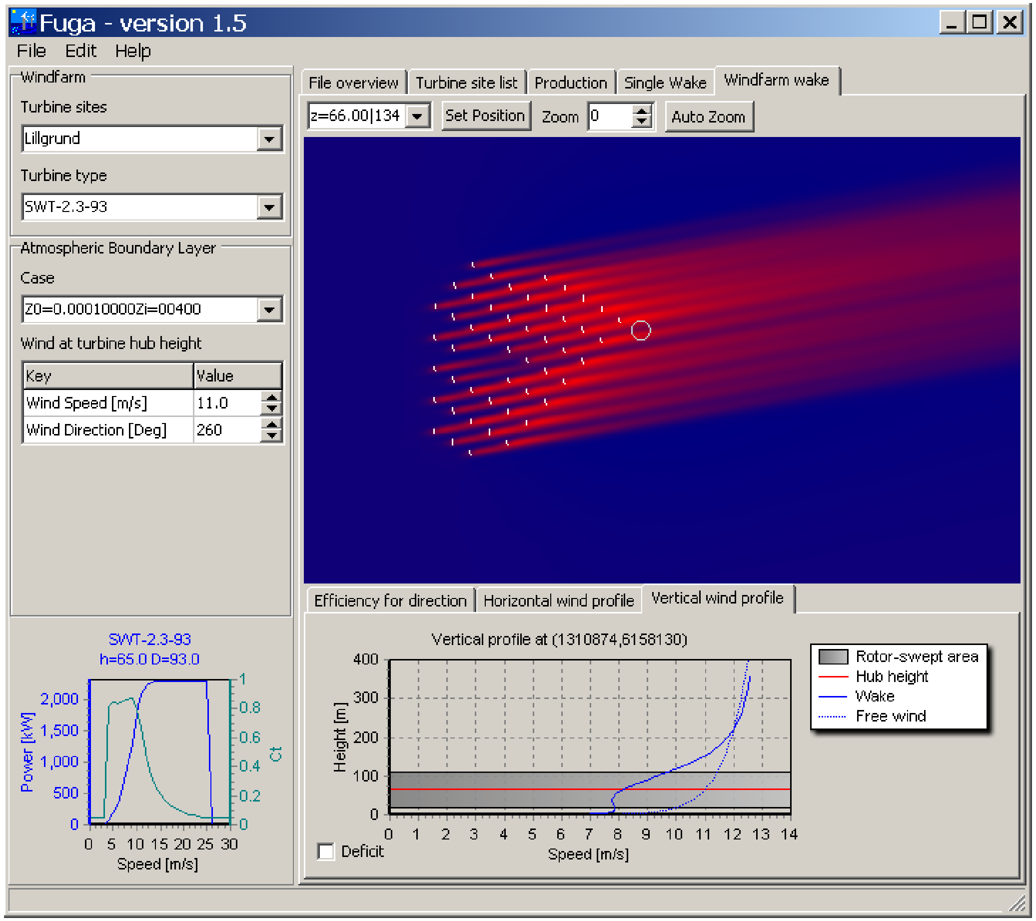
Wake effects:
- latest results with the Dynamic Wake Meander model



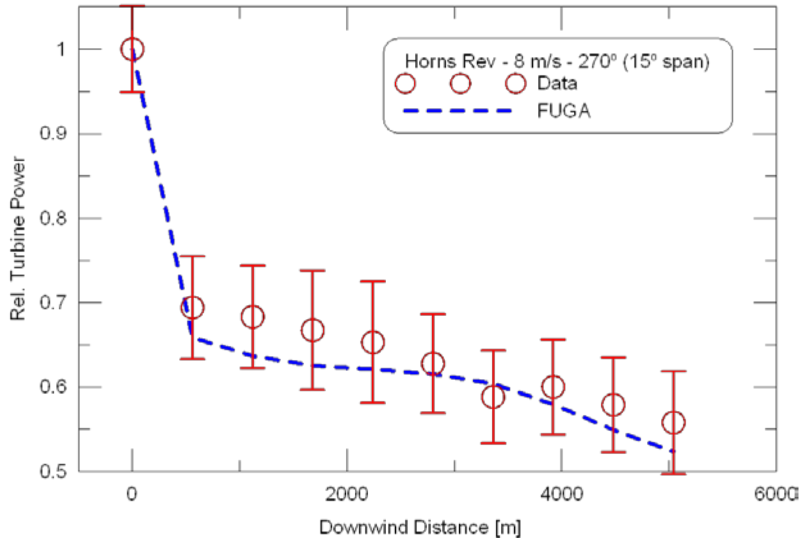
Fuga – a new wake model

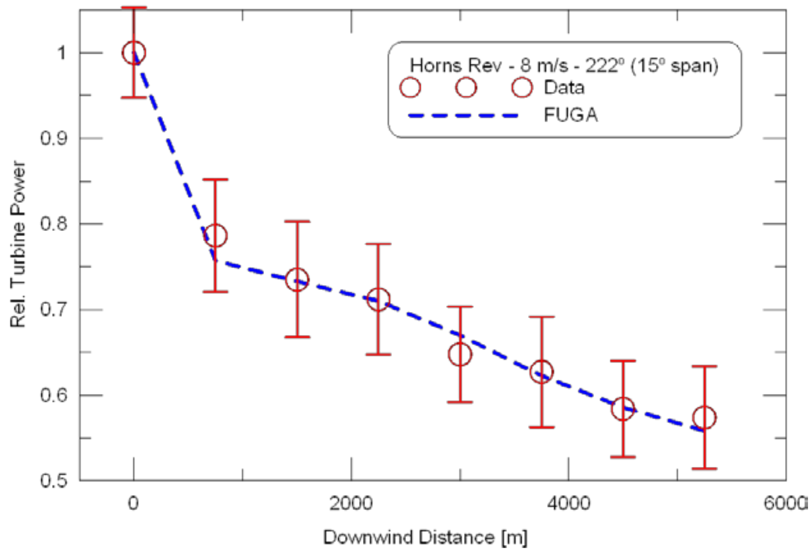
- Linearised CFD
- 10^6 times faster than conventional CFD
- Supported by Carbon Trust
- It Works!

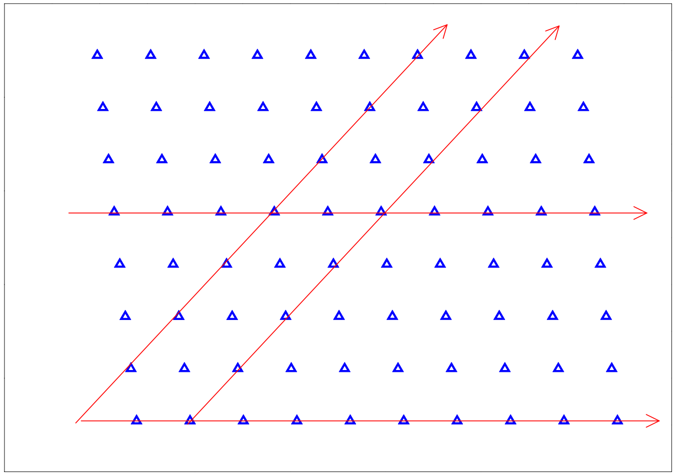




Validation: Horns Rev data. 8 m/s





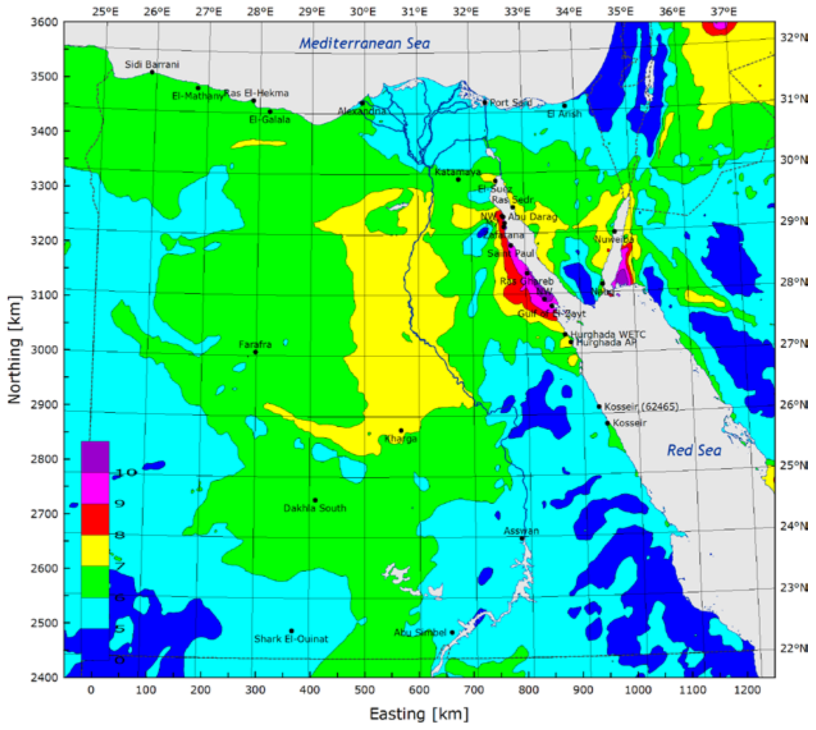


Simple closure: $\nu_t = \kappa u_* z$

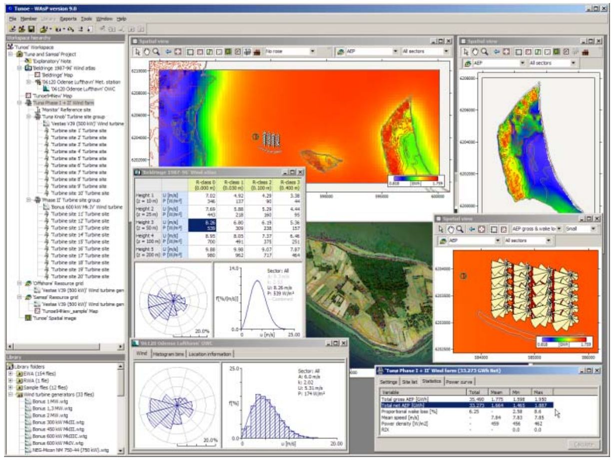
No adjustable parameters!

Wind Power Meteorology
tools and maps

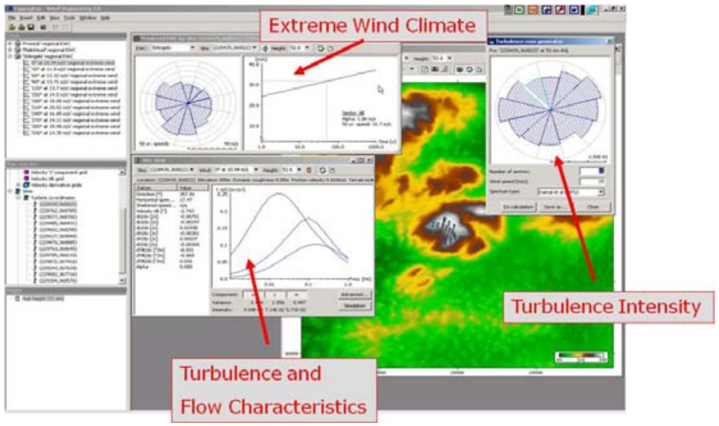
Wind Atlas for Egypt (2006)



WAsP – the Wind Atlas Analysis and Application Program



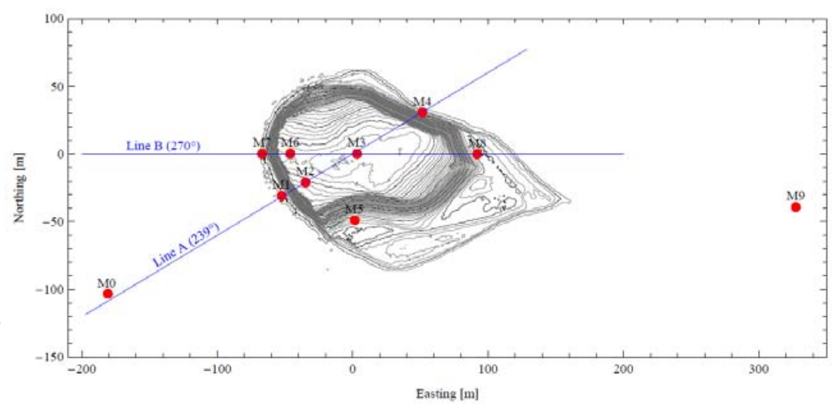
WAsP Engineering



Wind conditions in complex terrain

Bolund experiment

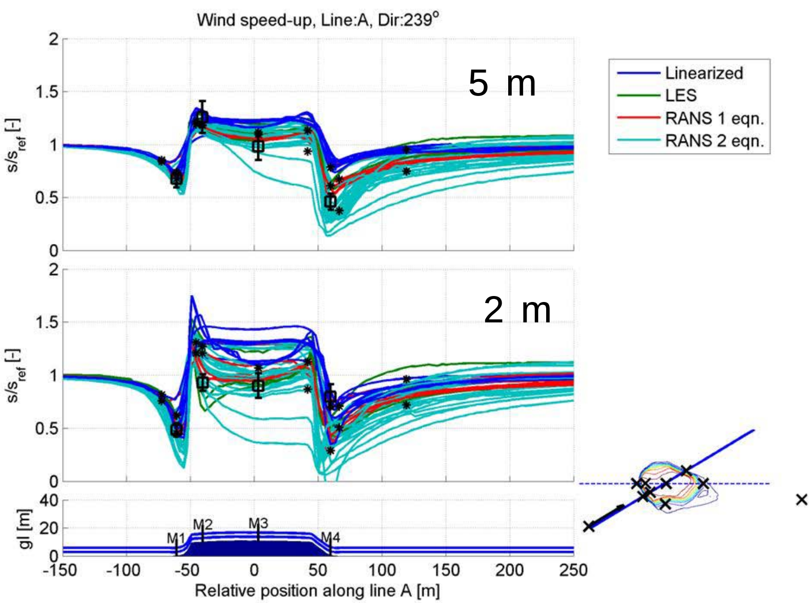
- Well-defined inflow conditions
- Roughness change
- Steep escarpment / “complex”
- Intercomparison study of numerical micro scale flow models



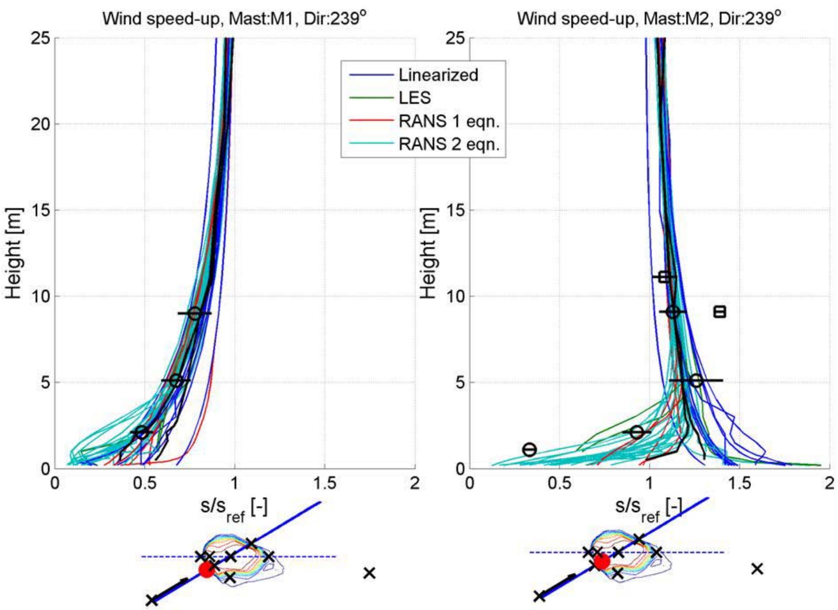
Mast Positions
CFD were used to find the 10 positions

Numerical results

Speed-up along line A

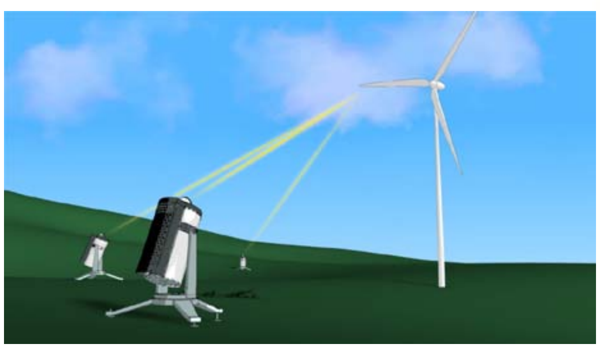


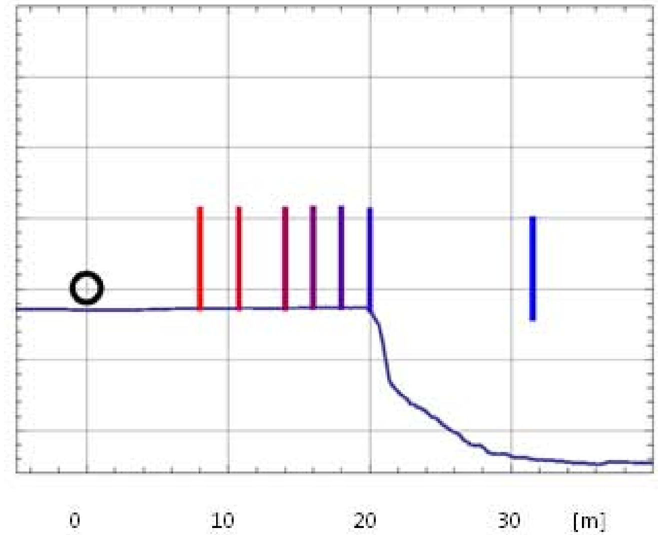
Speed-up at M1 & M2

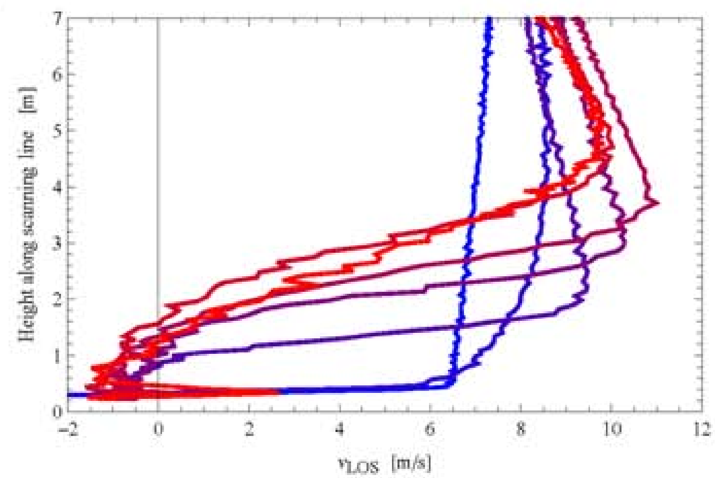


Mean Error: 26%
Linearized: 35%
LES: 26%
RANS 1 eqn.: 25%
RANS 2 eqn.: 20%

WindScanner.dk - Bolund Hill Experiment - October 2011:

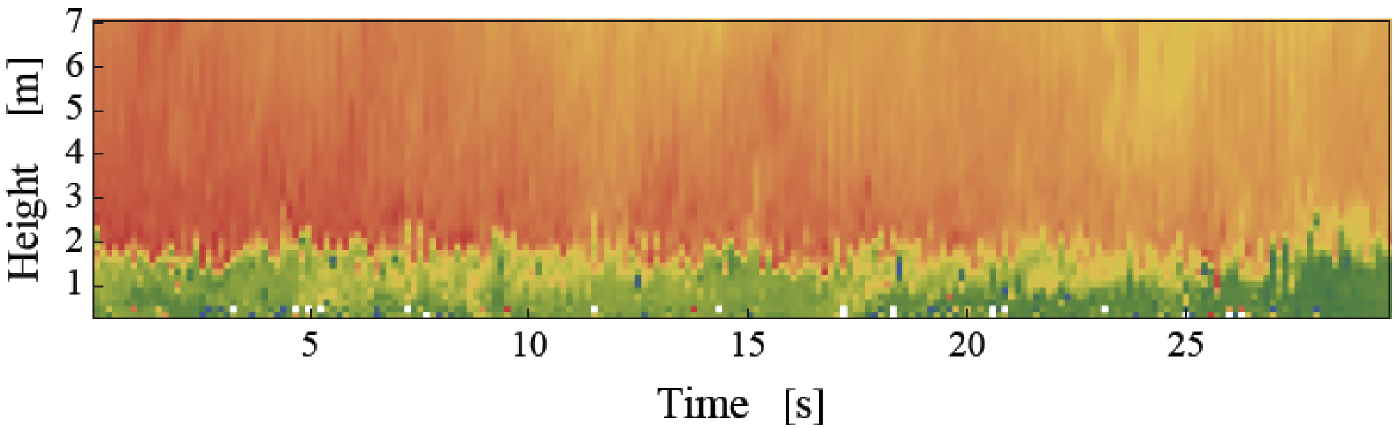


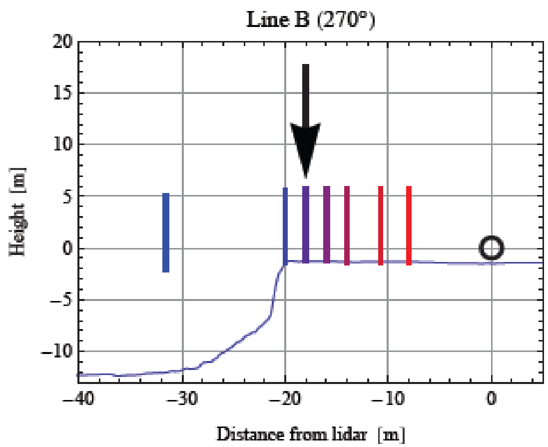


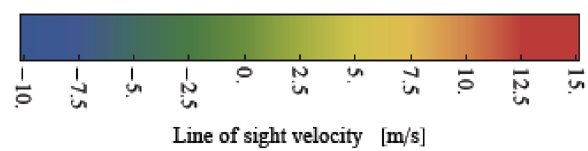


Half a minute of scanning data

390 line-of-sight velocities per second



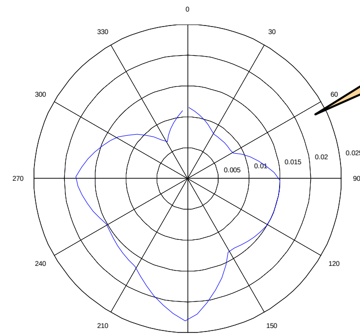


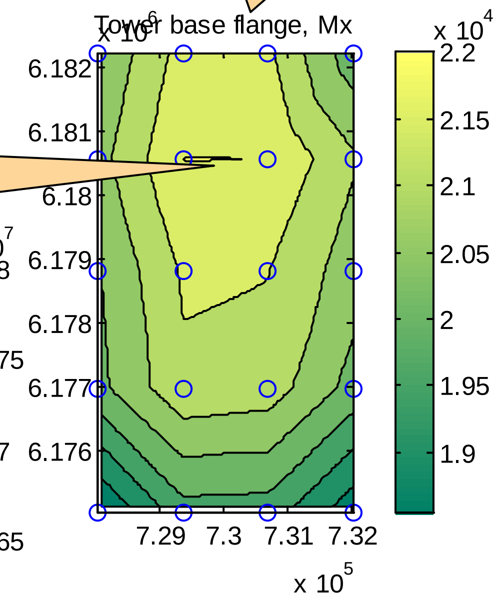


Topfarm wind farm optimization approach - loads and power

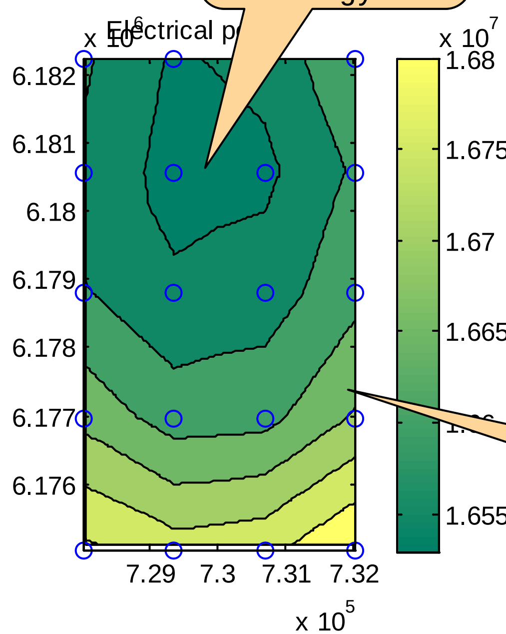
- Optimum wind turbines position for the lowest cost of energy
- Wake modeling using DWM (Dynamic Wake Meandering)
- Quick lookup for power and fatigue loads in a database based on HAWC2 aeroelastic simulations
- Cost function including: Annual energy production and costs of: Turbines, Grid, Foundation and O&M

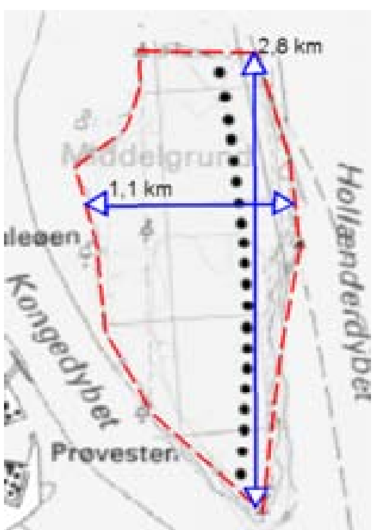
Example: A 20 WT wind farm

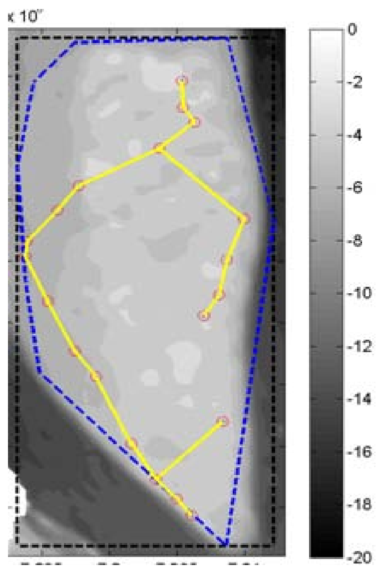




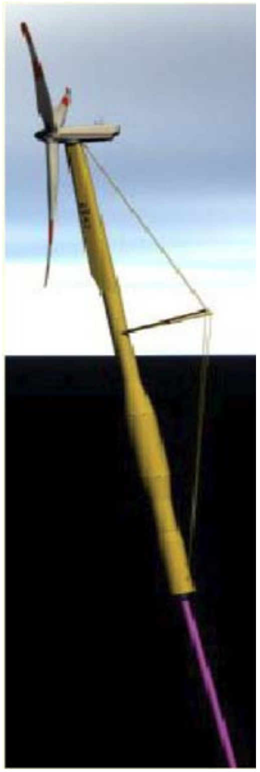
Turbines in wake have higher loads produce less energy!!



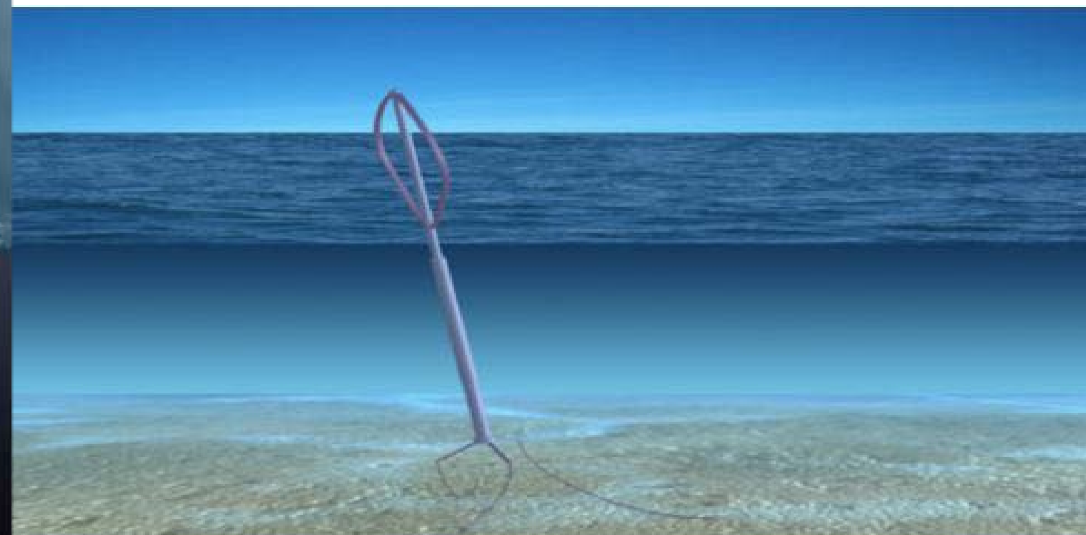


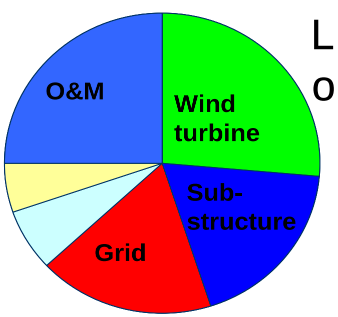


New concepts offshore



Floating turbines





Life cycle costs offshore

Combined wind and wave energy converters

Research, development and demonstration challenges – Danish MEGAVIND strategy

Planning and site selection	• Spatial and physical planning • Resource assessment
Farms with higher productivity and earnings	• Wind farm layout and wind farm control • Upscaling - larger rotor • Auxiliary services from wind farms • Offshore wind power plant in the energy system • Short term wind prediction
Efficient wind turbines	• Accelerated full scale test of turbine and components • Design conditions for reliable and multifunctional turbines in parks • Design basis for large offshore turbines in integrated park
Support structures	• Optimized manufacturing processes • Better and cost efficient foundations • New, cost-competitive foundations
Electrical infrastructure	• Voltage level and turbine rated capacity • Combining grid connection with interconnections between power systems areas
Assembly and installation	• Pre-assembly of standardised, stackable components at harbour • Modularisation and standardisation of substations and connection • Cable installation on seabed, quality and protection of cables in park
Operation and maintenance	• Risk-based cost-optimal O&M planning • Cost-optimal and weather robust mobile access

Target to make offshore wind power competitive with conventional coal-fired power by 2020 (50 % reduction in cost).

DTU Wind Energy - 2012

Quality
Scientific excellence

Technical University of Denmark
(founded 1829; first rector H.C. Ørsted)

Ranking

Leiden *Crown Indicator* 2010:
nr. 1 in Scandinavia
nr. 7 in Europe

Relevance
Strategic research programmes

Wind Energy Systems
- Wind resources and siting
- Wind power integration and control
- Offshore wind energy
- Wind energy and society

Wind Turbine Technology
- Aero-elastic design
- Structural design and safety
- Mechanical components
- Electro-technical components

Wind Energy Basics
- Aero and hydro dynamics
- Boundary-layer meteorology and turbulence
- Light, strong materials
- Remote sensing and measurement techn.

Impact
On society

Research

Innovation

Public sector support

Education

Conclusions

- Wind energy has been quite successfull in its development, introduction and penetration as a renewable energy technology – but it takes time
- The wind energy development has been a bottom-up process, where science has supported and accelerated the development rather than initiated
- The development has been a partnership between science and industry, where the role of science continously has been adapted to the needs and maturity of the industry
- Wind energy science/research is mission-driven – the goal being to advance and increase competitiveness of wind energy technology
- Hence, for wind energy research to be effective, it must have quality, relevance (strategic research) and create impact using appropriate mechanisms such innovation, private an public sector consulting and education.


Thank you for your attention